

Determination of Range of Splash of Testing Fluid during Hydro Testing of Knife Gate Valve

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ABSTRACT

There are certain trivial experimental findings which may not have a major significance but their execution is considered to be of such a nature as to complete the study in the specified area. Likewise in the field of hydro testing of valves and flow equipment, there is a basic requirement of operation of the same under influence of applied hydro pressure. This is required to determine the performance parameters like the thrust and the torque required to operate the equipment. While doing so, in addition to the qualitative requirements, an additional requirement of space has to be considered to ensure the surrounding area is not affected due to splashes of the testing fluid while under pressure. This paper shall consider such a case for hydro testing of a knife gate valve. At a given pressure, when the door or gate of the valve is initiated to open, there is an initial splash of testing fluid which ejects out of the orifice created due to the opening. The horizontal range of this splash shall be mathematically determined. An experimental finding shall then be presented to confirm the derived formulae. A conclusion shall be drawn thereafter dictating the percentage error and the employability of the derived formulae.

KEYWORDS: Range, splash, hydro, testing, valve

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A. Introduction to Knife Gate Valves

Knife gate valves belong to the family of block valves which may also be known as on-off valves. These valves are primarily used in demanding applications like sludge, slurry, pulp, paper and so on where the working fluids are relatively thicker and need to be cut through with the aid of a knife gate. These valves are available in metal seat and soft seat options according to the requirement of the application. Various types of actuations like manual, pneumatic, gear and motorized electrical modes make these valves one of the most versatile and sought after for the stated applications.

B. General requirements and procedure of hydro testing

Hydro testing refers to the process of ensuring no leakage in the valve under a certain conditions. There are numerous governing standards that can be referred in order to design hydro testing procedures but the collective purport of all of them is somewhat similar.

Every valve needs to be subjected to a shell test prior to the commencement of manufacturing activities. Shell test is essentially carried out to confirm the ability of the valve housing which is generally a casting to withstand the rated hydro pressure. This test can provide results that can be used to approve the casting quality and the overall design of the housing.

Seat test is the next type of test conducted for industrial valves. The purpose of carrying out a seat test is to ensure

that the valve trim components are accurately machined and aligned to provide the necessary sealing as dictated by the reference standards.

There are a number of types of seat test. While checking for hydro or testing liquid leakage, the upstream is pressurized with the valve being in closed position and leakage is checked on the downstream side. While checking for air leakage, the downstream side is completely filled with the testing liquid and the upstream side is supplied with air and the occurrence of bubbles is noted. In addition to these, there is a back seat test that is carried out to ensure there is no leakage through the interface between the enclosure and the trim, particularly the spindle or stem.

However from the perspective of safety, during the testing, there are numerous factors that need attention. The study presented in this paper is in that direction itself.

C. Hydro testing of knife gate valve

Knife Gate Valves are designed as a cuboids housing. By this, it can be understood that most of the surfaces are flat. This is a major concern as far as the shell test is concerned because a flat surface spread over a relatively large area is prone to distortion. Taking this point into consideration, certain design modifications liking suitable ribbing may be provided for strength and sturdiness.

Shell test in case of a Knife Gate Valve is performed by mechanically sealing the bore and stuffing box by means of plates and gaskets. The objective of shell test is to check for leakages through the housing on application of pressure. According to MSS SP81, the testing pressure shall be 1.5 times that of the rated pressure. However, there is no specification as to what should be the value of rated pressure and that remains the designer's choice owing to the competitiveness of the product. Shell test is more or less a crude method because it merely gives a confirmation of the wall thickness safety and the fact that the casting under shell test is free from casting defects that may bear the potential to cause leakages.

Seat test in Knife Gate Valves as per MSS SP81 is recommended to be performed at a differential pressure of 2.8 kg/sq.cm (g) wherein certain allowable leakages are mentioned. However over the years on account of mutual competition, some manufacturers claim to provide zero leakage which is indeed desirable but requires proper machining.

These are the two prescribed tests for Knife Gate Valves. Apart from these, at large, there are no other tests required to claim that the valve is ready to be commissioned.

While designing the valve, certain performance parameters need to be calculated which include the flow rate, friction factor, pressure drop, flow coefficient, thrust and torque. A little consideration will make it evident that all these factors are linked to the line pressure or the pressure force acting on the gate.

The friction factor due to fluid friction is an effect of the force on gate due to the line pressure. Friction factor for various other parts may be either referred from available literature or may be determined experimentally.

Although the standard does not specify a mandatory requirement of the same, it is necessary to carry out another qualitative test to ensure the valve operation can be carried out easily in the presence of line pressure. This shall provide a validation of the calculated performance parameters.

D. Line pressure operation test and range of splash

In the installed condition, the valve needs to have an ability to open or close against the line pressure when cutting through the flow media. In order to ensure this, an additional qualitative test can be performed as follows.

This test requires the valve to be mounted and clamped on the test rig and pressure shall be applied at the upstream side. The downstream side may be open or closed. While the valve is in this condition with line pressure acting on the upstream side, the gate shall be opened to check whether operation is possible against line pressure. The test may be said to be successful if excessive additional force is not required to open or close the valve.

During this test, fluid pressure acts on the upstream side. On initiating the opening action, once the tip of the gate just crosses that of the bore, an orifice is created which

serves as an opening. This orifice initiates a splash corresponding to the pressure. However, with time, the pressure is relieved and the range of splash goes on decreasing. The maxima of the range of splash is at the instant the orifice is generated.

According to Pascal's Law, pressure acts equally in all directions in a static condition. Although there is a pressurization in process, as the gate is closed, at an infinitesimal level, it can be assumed that static conditions are well maintained. As a corollary, as the pressure containing volume is introduced with an opening, the fluid tends to escape through it in the direction of lower pressure which in this case is the ambient pressure. While doing so, there is a stream of splash that can be observed which escapes with a certain velocity corresponding to the upstream pressure and lands at certain distance which can be termed as the range of the projectile. Further sections shall elaborate this concept in detail.

E. Significance of determination of range of splash

When the valve is installed at site, it is quite uncertain whether the valve is being used for line intermediate services or for dead end service.

For line intermediate services, the valve is generally used as an isolator to isolate a certain section of the pipeline. In this case, once the valve is supposed to be opened, the splash will be within the pipeline and there will not be any special effect on the ambience surrounding the pipe. This makes it feasible for all types of flow media to be employed without any additional precautions.

When the valve is being used for dead end service, there are certain key factors which make this study valuable. These include nature of flow media, space constraints and line pressure. There are certain flow media that are corrosive in nature. Spillage of the same in the ambience can cause serious damage to the equipment, men and material kept nearby. However it is also necessary to know the range of splash to plan the site layout. Space constraints may pose certain dangers to other equipment if reactive material is splashed all over. At the same time, it may not be to provide guards everywhere because of cost concerns. Line pressure greatly governs the range as it exhibits a direct proportionality. Greater the line pressure, greater will the velocity and hence the range of splash.

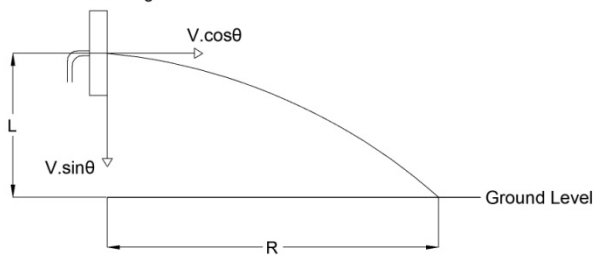
In addition to the site concern, there is another concern at the manufacturing facility itself which is the space constrain and the presence of human resource in the vicinity. During the procedure of hydro testing at the manufacturing facility, the test fluid used is generally water which may be at times added with certain corrosion inhibitors. It is necessary to keep the designated area clear from men and material to avoid potential damage of any kind.

F. Determination of Range of splash from first principles

In this section, an equation to determine the range of splash of fluid from orifice during line pressure operation test shall be derived from first principles.

Consider the following figure.

Valve mounted on Test Rig



From the figure, it can be observed that a valve is mounted on the test rig at a certain height from the ground level.

Consider an orifice created due to an infinitesimal opening in the flow area whose centroid is at a distance 'L' from the ground level.

Considering SI Units,

Let P = Line pressure

V = Instantaneous orifice splash velocity at opening

$V \sin \theta$ = Vertical component of splash velocity

$V \cos \theta$ = Horizontal component of splash velocity

R = Horizontal range of splash

According to the Hydrostatic law, the Pressure ' P ' can be expressed in terms of an equivalent head ' H '

$$P = \rho \cdot g \cdot H \quad \dots(1)$$

Where ρ = Density of flow media

g = Acceleration due to gravity

H = Height of fluid column i.e. head

On further simplification,

$$H = P / (\rho \cdot g) \quad \dots(2)$$

Thus the head corresponding to the line pressure can be calculated.

For flow through orifices, corresponding to a head ' H ', the velocity of flow through the orifice can be given by the following expression available in literature[1].

$$V = \sqrt{2 \cdot g \cdot H} \quad \dots(3)$$

This expression provides the velocity against a static head ' H '.

Considering the third equation of motion which is as follows:

$$S = u \cdot t + 0.5 \cdot a \cdot t^2 \quad \dots(4)$$

Where S = Displacement of projectile = L

u = Initial velocity = $V \sin \theta$

t = Time taken

a = Acceleration = g

Substituting the values, Equation (4) can be written as

$$L = V \sin \theta \cdot t + 0.5 \cdot g \cdot t^2 \quad \dots(5)$$

Since the vertical component of velocity is zero as at the instant of opening the trajectory is horizontal, Equation (5) reduces to the following.

$$2L = g \cdot t^2 \quad \dots(6)$$

$$t = \frac{\sqrt{2L}}{g} \quad \dots(7)$$

At the instant of release of the splash from the orifice, the product of horizontal component of the velocity i.e. $V \cos \theta$ and the time as calculated from Equation (7) shall give the expression for Range of splash.

$$\therefore R = V \cos \theta \cdot t \quad \dots(8)$$

Equation (8) gives the magnitude of range of splash at a velocity V corresponding to a pressure P .

G. Experimental confirmation of derived equation

It is necessary to verify and confirm the equation derived for range of splash. The same shall be elaborated in this section.

An experiment was conducted to verify the correctness of the formula. A Knife Gate Valve of 150 mm nominal diameter was mounted on the testing rig and the upstream was pressurized to 3 kg/sq.cm(g). The distance of orifice from the ground shall be assumed to be unity which is close to the actual value. When the valve was just opened, a splash was observed the maximum range was which was observed to be around 10.5 m. This shall be verified by calculations using the derived formulae as follows.

Corresponding to the upstream pressure, the pressure head is:

$$H = 29.9898 \text{ m}$$

Using Equation (3),

$$V = 24.256 \text{ m/s}$$

Using Equation (7),

$$t = 0.4515 \text{ s}$$

Since the angle of flow at the orifice is 0° , $\cos 0^\circ = 1$

Using Equation (8),

$$R = 10.952 \text{ m}$$

The percentage error observed is 4.12%

Conclusion

Thus it can be concluded that percentage error in the values of range of splash as obtained from the formula and that observed during the experiment is 4.12% which clearly indicates that the formula can be used to determine the range of splash during the hydro testing. The information obtained thereof can be useful to prepare the area for testing. In addition to this, the concept can be helpful with regards to safety at site where the valves are being used for dead end services.

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